Diagnostic Ultrasound Imaging in Domestic Animals: Fundamental Studies on Abdominal Organs and Fetuses

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The abdominal organs and the fetus of normal cows, horses, goats and dogs were investigated by the use of ultrasonotomography. 1) Liver & gall bladder: In cows and goats, the liver was imaged on the right side between the 8th and 12th intercostal spaces. Clear ultrasound images of the canine liver were obtained by subcostal scanning. In horses, however, only the parenchymal margin was visualized. In cows, goats and dogs, the parenchyma, portal vein, hepatic vein and gall bladder showed characteristic echo patterns, respectively, but the appearance of the bile ducts was obscure. 2) Spleen: In each animal, the ultrasound images of the spleen were obtained on the left side in the lower intercostal spaces; in horses and dogs, the same was obtained also in the flank. The spleen appeared as the characteristic low amplitude echo pattern. 3) Kidney: In cows and goats, each kidney was displayed on the right flank, and the right kidney was also observed in the 12th intercostal space. In horses and dogs, each kidney was visualized in the lower intercostal spaces and the flank. In all animals, echoes of the kidney were composed of a low amplitude echo pattern showing the renal cortex, an echo free pattern exhibiting the medulla and an echogenic pattern indicating the pelvis. 4) Fetus: The fetus and fetal organs of cows, goats and dogs were imaged by transcutaneous scanning in the lower abdomen or flank. Fetal movement and fetal heart contractions were detected by real time ultrasonotomography.—*Key words:* Abdominal organs, Animals, Fetus, Ultrasonotomography.

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Diagnostic ultrasound imaging is a noninvasive, safe method for assessment of structures and tissue consistency in various organs. But ultrasound cannot penetrate lung tissue, gas-filled bowel and bone tissue. The method is well established in human medicine as a valuable imaging modality. Moreover, no biohazard in diagnostic ultrasound has been reported as yet [2].

Since 1966, amplitude mode(A-mode) ultrasound has been used as an aid in pregnancy diagnosis in sheep[10]. In recent years, with the development of motion mode(M-mode) and grayscale brightness mode(B-mode)ultrasound, the use of diagnostic ultrasound imaging has been extended to the heart[16, 21] and abdominal organs[8, 9] in veterinary medicine, and some workers have reported the use of B-mode ultrasound in clinical cases of the

abdomen[3, 4, 5, 12] and the thorax[18]. Basic scan interpretation, artifact recognition and the physical principles of ultrasound have been discussed elsewhere[15, 17]. However, concerning its use in the abdomen of domestic animals, there are few detailed reports on the scanning positions or the image patterns, apart from some fundamental reports demonstrating clinical cases[6, 13, 19]. In this study, therefore, the abdominal organs and the fetus of normal cattle, horses, goats and dogs were investigated fundamentally by the use of ultrasonotomography.

MATERIALS AND METHODS

Animals: 1) Normal animals: Eighteen Holstein cattle(10 cows, 4 calves, 4 sucklings), four horses(3 adult mares and 1 suckling), six Saanen goats(3 bucks and 3 does)

and seven adult mongrel dogs were used in the study on normal cases. These animals were clinically healthy. 2) Pregnant animals: Five Holstein cows, three Saanen goats and three dogs, which have been diagnosed clinically as being pregnant, were used in the study on pregnant cases.

Equipment and recording method: An electronic linear scanner for ultrasonotomography (Tomosonic EUB 25-M, Hitachi Medical Corp., Tokyo, with 3.0, 3.5 and 5.0 MHz transducers) was used in this study. A gray scale, B-mode ultrasonotomogram was viewed on a TV monitor screen of the scanner with the real time function. After an image was frozen on the CRT screen, photographic recordings were made using Polaroid 611 films (Polaroid Corp., Cambridge) and a Polaroid camera.

Image presentation: All scans were done in white on a black background. Image presentation in the small animals made following in principle that used of man[1]. In the standing large animals, transverse and longitudinal scans were oriented as though the viewer were observing the animal from the caudal aspect. In addition, both scans were presented so that the images of the body surface could coincide with the incident direction of the ultrasound beam[15].

Experimental procedures: Scans were done on standing cattle, horses and goats, with exception of recumbent sucklings. Dogs were rarely tranquilized and examined in the standing, sitting, supine and recumbent positions. The skin surface of the area to be examined was clipped and cleared. Aqueous gel was used as a coupling agent between the skin and the transducer surface. The transducer was held perpendicular to the skin surface of the underlying organs whenever possible. Animal motion was controlled as needed.

Objective organs and scanning position: The liver, gall bladder, spleen and kidney were investigated in each animal. The area

of the body surface in which the organ was located anatomically was explored with the transducer in the real time display. The area where the clear ultrasound image of the organ was obtained was determined as the scanning position. At the same time, the direction of the transducer was also confirmed. The observed and obtained images were examined with respect to the shape, internal echo and adjacent organs of the objective organ. The fetus was investigated in the area of the lower abdomen in pregnant animals and observed.

Identification of echoes in organs: 1) Abdominal organs: After examination, the experimental animals were euthanatized. The location of each organ and the incident direction of the ultrasound beam were confirmed after the removal of the skin, intercostal muscle and diaphragm in standing or recumbent animals. Subsequently, the excised organs, which was suspended in a tank filled with water, was scanned in the same direction as that for the transcutaneous approach. 2) Fetus: The presence of the fetus was determined by the movement of the fetal heart and the fetus itself in real time ultrasonotomography and recognized by the delivery.

RESULTS

The present results of scanning positions and image patterns on domestic animals were summarized in the Table 1. The detailed results on each organ and the fetus were as follows, respectively.

I. Liver and gall bladder

Cattle and Goats: On the right side, the liver was imaged by intercostal scanning in the area ventral to the level of the shoulder joint between the 8th and 12th intercostal spaces when the transducer was oriented somewhat cranially. In particular, the 10th and 11th spaces were easiest to scan and provided the most agreeable images. The liver was visible ventral to the lung border and external to the pancreas, intestine and omasum or rumen (Fig. 1). The hepatic

Table 1. Scanning positions and imaging patterns of abdominal organs and fetus of domestic animals

Organs	Items	Cattle & Goats (Standing)	Horses(Standing)	Dogs (Standing, sitting, supine, recumbent)
Liver	Scanning position	R-8-12 ICS ^{a)} : ventral to the level of S-J ^{b)}	R-10-14 ICS: ventral to the level of S-J	Subcostal & L-R-9-12 ICS: ventral
	Internal echoes	Parenchyma; low amplitude and multiple fine echo pattern		
	Remarks	Portal vein, Hepatic vein (Caudal vena cava ^{c)}) Only the parenchymal margin seen Pancreas, Pancreatic ring	Diaphragm, Between respiratory and peristaltic movement	Portal vein, Hepatic vein, Caudal vena cava Diaphragm
Gall bladder	Scanning position	R-10, 11 (9, 10) ICS: near (ventral to) the costal arch		Same position as the liver
	Internal echoes	Echo free		Echo free
Spleen	Scanning position	L-11, 12 (8-12) ICS: dorsal	L-8-17 ICS: ventral to the level of S-J & Ventral area of L-F ^{d)}	Left lower ICS & L-F
	Internal echoes		Homogenous and low amplitude echo pattern	
Kidney	Remarks	(Abdominal aorta)	Acoustic window for imaging the left kidney	Mobile
	Scanning position	R-K ^{e)} ; R-12 ICS: dorsal & Dorsocranial area of R-F	R-K; R-16, 17 ICS: dorsal	L-R-12 ICS: dorsal & Near the 13th rib on L-F or R-F
	Internal echoes	L-K; Dorsocaudal or central area of R-F	L-K; L-16, 17 ICS: dorsal & Near the 18th rib on L-F	
Fetus	Remarks	Cortex; low amplitude echo, Medulla; echo free, Pelvis; echogenic (high amplitude echo)		
	Scanning position	Caudal vena cava, Renal vein	Spleen	Spleen
Fetus	Scanning position	Ventral to R-F (Lower abdomen)		Lower abdomen
	Observed images	Fetal organs, Fetal movement, Fetal heart contraction, Fetal fluid, Placenta, Umbilical cord		

a) R(L)-8-12 ICS=On the right (left) side between the 8th to 12th intercostal spaces.

b) S-J=shoulder joint.

c) ()=The terms interposed within () supplement items on goats.

d) L(R)-F=left (right) flank.

e) R(L)-K=right (left) kidney.

Fig. 1. Ultrasonotomogram (USG) of the liver and gall bladder in a cow.

Ultrasonotomogram (USG) is shown in the left side of the figure, the schema in the right. Side markers are 1 cm apart. The relative position of the transducer (or USG) on the body surface is indicated above or besides the schema, coinciding with the incident direction of the ultrasound beam. The intercostal space to be scanned is shown under the schema. USG in cows, horses and goats was obtained by using 3.5 MHz transducer, in dogs 5.0 MHz.

D: Dorsal, V: Ventral, R-11: Right 11th Intercostal Space, BW: Body Wall, Li: Liver, GB: Gall Bladder, PV: Portal Vein, Pa: Pancreas, Int: Intestine, Om: Omasum, SL: Side Lobe.

Fig. 2. USG of the liver in a cow.
HV: Hepatic Vein. See also Fig. 1.

parenchyma, whose margin was visualized as a somewhat wedge shaped pattern, had comparatively low amplitude and multiple fine echo patterns (Fig. 1). Portal veins appeared as transonic rounds, star shaped configurations or somewhat tortuous channels with surrounding echogenic definition, while hepatic veins appeared as transonic ovals or straight channels with no echogenic border (Fig. 2). The travelling direction of the portal veins was always different from that of the hepatic veins. In addition, the main portal vein, which enters the hepatic hilus from the pancreatic ring after passing through the pancreas, was observed. However, no clear images of the bile ducts were obtained. In goats, the caudal vena cava was also observed dorsal to the main portal vein.

The gall bladder was visualized as an echo free oval or a long-ellipse near the costal arch on the right side from the 10th to 11th intercostal spaces in cattle (Fig. 1), and in the area ventral to the arch from the 9th to 10th spaces in goats.

Horses: The liver of adult mares was imaged on the right in the area ventral to the level of the shoulder joint from the 10th to 14th spaces, however, the parenchymal margin was only visualized between respiratory and peristaltic movement (Fig. 3). The liver

was identified as being ventral to the lung border and medial to the diaphragm, which was imaged clearly. In a left recumbent suckling, the pattern of the liver was similar to that of the cattle.

Dogs: The liver and gall bladder were visualized on both sides of the body near the subcostal area and in the area ventral to the midway of the rib cage from the 10th to 12th intercostal spaces when the transducer was directed cranially in each position. The liver contained echoes of the parenchyma, portal vein, hepatic vein and caudal vena cava. The caudal vena cava was exhibited as a transonic oval or two parallel linear structures with pulsations (Fig. 4). The liver was surrounded by the diaphragm, stomach and bowel.

II. Spleen

Cattle and Goats: On the left side, the ultrasound images of the spleen were obtained by intercostal scanning dorsal to the area from the 11th (8th) to 12th intercostal spaces in cattle (goats), orienting the transducer cranially. The spleen was visible ventral to the thoracic vertebrae and external to the rumen, and had a characteristic low amplitude echo pattern (Fig. 5). In goats, the abdominal aorta was imaged dorsal and medial to the spleen.

Horses and Dogs: In horses, the spleen

Fig. 3. USG of the liver in a horse.
Di: Diaphragm. See also Fig. 1.

Fig. 4. Longitudinal scan of the liver in a supine dog.

Cra: Cranial, Cau: Caudal, CVC: Caudal Vena Cava, S: Spleen, St: Sternum. See also Figs. 1, 3.

Fig. 5. USG of the spleen in a cow.

Sp: Spleen, Ru: Rumen, VB: Vertebral Body, L-12: Left 12th intercostal space. See also Fig. 7.

was detected on the left side in the area ventral to the level of the shoulder joint between the 8th and 17th intercostal spaces, and in the ventral area of the flank; in dogs, it was detected in the lower spaces and in the left flank. A spleen having a low amplitude echo was observed ventral to the lung border, medial to the diaphragm and external to the alimentary tracts and the left kidney, and it was so mobile that its position or general configuration at imaging was variable.

III. Kidney

Cattle and Goats: The right kidney was

displayed in the dorsal area of the right 12th intercostal space when the transducer was oriented caudally, and at the dorsocranial area of the right flank when it was oriented to the left side. At the same time, the bowel, liver and caudal vena cava were also seen. The left kidney was imaged at the dorsocaudal or central aspect of the right flank; it was not imaged in all the cattle, while it was imaged in all the goats. The rumen was visible medial to the left kidney. Bovine kidneys appeared as lobulated structures with low amplitude echo patterns showing the renal

cortex, echo free patterns exhibiting the medulla and echogenic patterns representing the pelvis (Fig. 6); caprine kidneys appeared as ovoid structures. And in cattle, renal veins were also observed in the transverse kidney scans.

Horses and Dogs: Each kidney was imaged at the dorsal aspect of the lower intercostal spaces (16th and 17th in horses and 12th in dogs), and near the last rib of the flank (only the left kidney in horses). The kidney appeared as the same pattern as in goats. In horses, the left kidney was identified medial

to the spleen, but longitudinal renal images could not be obtained due to echoes from the ribs and bowels. In dogs, transverse and longitudinal renal images were obtained easily (Fig. 7). The spleen was also observed at imaging of the left kidney (Fig. 7).

IV. Fetus

The fetus, fetal organs, fetal fluid, placenta and umbilical cord of cows, goats and dogs were visualized by scanning from the body surface of the lower abdomen and/or flank (Fig. 8). Fetal movement and fetal heart contractions were observed by real time ultra-

Fig. 6. Longitudinal scan of the right kidney in a cow.

K: Kidney, Cor: Cortex, Med: Medulla, Pel: Pelvis, A-S: Acoustic Shadow. See also Figs. 1, 4.

Fig. 7. Longitudinal scan of the left kidney in a recumbent dog.

L: Left. See also Figs. 1, 4, 6

Fig. 8. USG of a bovine fetus of 5 months of fetal age.
UtW: Uterus Wall, FH: Fetal Heart. See also Figs. 1, 5.

sonotomography. In cows, the fetus could be visualized from 4 to 7 months of fetal age, but one under 3 months could not be imaged by the transcutaneous technique.

DISCUSSION

The image pattern which indicated echoes from the liver was composed of the parenchyma and intrahepatic luminal architectures (Fig. 1, 2, 4) resembling those of man [7] and dogs [6, 8, 9, 13]. Portal veins showing luminal patterns with surrounding echogenic definition, and hepatic veins indicating them with no echogenic border have been called intrahepatic luminal architectures [6, 7]. This study also showed a similar pattern, in addition to a difference in the travelling direction (Fig. 2). It appeared that these image patterns are important in distinguishing portal veins from hepatic veins on the display.

In cattle and goats, although it was presumed that the observed liver was mainly limited to the right lobe, it was thought that the imaged region was significant clinically. In adult horses, the liver was not observed sufficiently in the present study by linear scan, or in another study by sector scan [19], because the liver remained partially concealed by the lung (Fig. 3). In dogs, subcostal scanning proved to be suitable for imaging the liver

rather than intercostal scanning, which tended to result in an acoustic shadow by the ribs.

This finding was supported by the fact that it was considerably difficult to image the canine liver with the sector scan method by intercostal scanning, due to some anatomical cause [8, 9, 13].

In this study, the appearance of the bile ducts was obscure in each animal; however, since dilatation of the ducts was recognized in cases of bile congestion in cattle [12], it was considered that the ducts are more easily detected in clinical cases than in normal ones.

The spleen had the same echo pattern as that reported in horses [19] and dogs [6, 8, 9]. In cattle and goats, it was thought that the spleen to be imaged was limited to a part of the whole spleen (Fig. 5), whereas in horses and dogs, most parts could be imaged from the extensive scanning positions.

Whether the bovine left kidney was detected was dependent on the amount of rumenal contents, since the rumen was visible medial to the left kidney. In order to obtain a clear appearance of the bovine kidneys, especially the left kidney, it is necessary to exert pressure leftward on the right flank with the hand and the transducer. On one hand, in horses, the spleen should be used as an acoustic window for imaging the left kidney, as des-

cribed also by Rantanen *et al.* [17]. On the other hand, in dogs examined in a standing, sitting or recumbent position, it is thought that an approach from back in the flank or in the last intercostal space is useful for imaging the kidneys in the presence of bowel gas rather than from the abdomen. This view agrees with that of Cartee[5] and Nyland *et al.* [13].

In this report, a clear distinction was drawn between the renal cortex and the medulla(Fig. 6, 7), which has not been done previously[5, 8, 9]. This was considered to be due to the improved resolution of the electronic scan method.

Since the bovine fetus under three months of fetal age was detectable by the intrarectal technique, it was assumed that ultrasonic examination is useful for early pregnancy diagnosis by intrarectal scanning, as reported in horses[14]. On one hand, it is believed that the diagnosis of fetal life is performed more easily and visually by real time ultrasonotomography than by fetal electrocardiography[20] and the Doppler method[11], because both the movement of the fetal heart and the fetus itself can be observed.

At this time, ultrasonotomography has accurately provided the size, shape, position, internal structure and spatial relationships of the abdominal organs and the fetus in normal domestic animals.

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要 約

家畜における超音波映像診断に関する研究——腹部臓器および胎仔についての基礎的検討：山我義則・戸尾 祺明彦（北海道大学獣医学部附属家畜病院）——健康な牛・馬・山羊・犬の腹部臓器ならびに胎仔を超音波断層法により映像化した。1) 肝・胆嚢：牛・山羊の肝臓は右側第8～11肋間隙肩端線位腹側で映像化された。犬では肋骨弓下走査により肝臓の明瞭な超音波断層像が得られたが、馬の肝臓では、実質辺縁のみが観察された。牛・山羊・犬においては、肝実質、門脈、肝静脈ならびに胆嚢は、各々特徴的なエコーパターンを示したが、胆管像は不明瞭であった。2) 脾臓：各動物種とも、脾臓の超音波断層像は左側後位肋間隙にて得られ、馬・犬では、臍部においても得られた。全動物種において、脾臓は低レベルのエコーパターンを示した。3) 腎臓：牛・山羊の両側腎臓は、右側臍部で映像化され、右腎は第12肋間隙でも観察された。馬・犬では後位肋間隙ならびに臍部で映像化された。全動物種において、腎臓エコーは腎皮質を示す低レベルエコーパターン、髓質を表わすエコーフリーパターン、腎盂を示す高レベルエコーパターンから構成されていた。4) 胎仔：牛・山羊・犬の中腹部または臍部における経皮的走査により、胎仔ならびにその各臓器が映像化された。実時間超音波断層法により、胎動ならびに胎仔心臓拍動が捕捉された。